Advancing Energy Equity in Grid Planning

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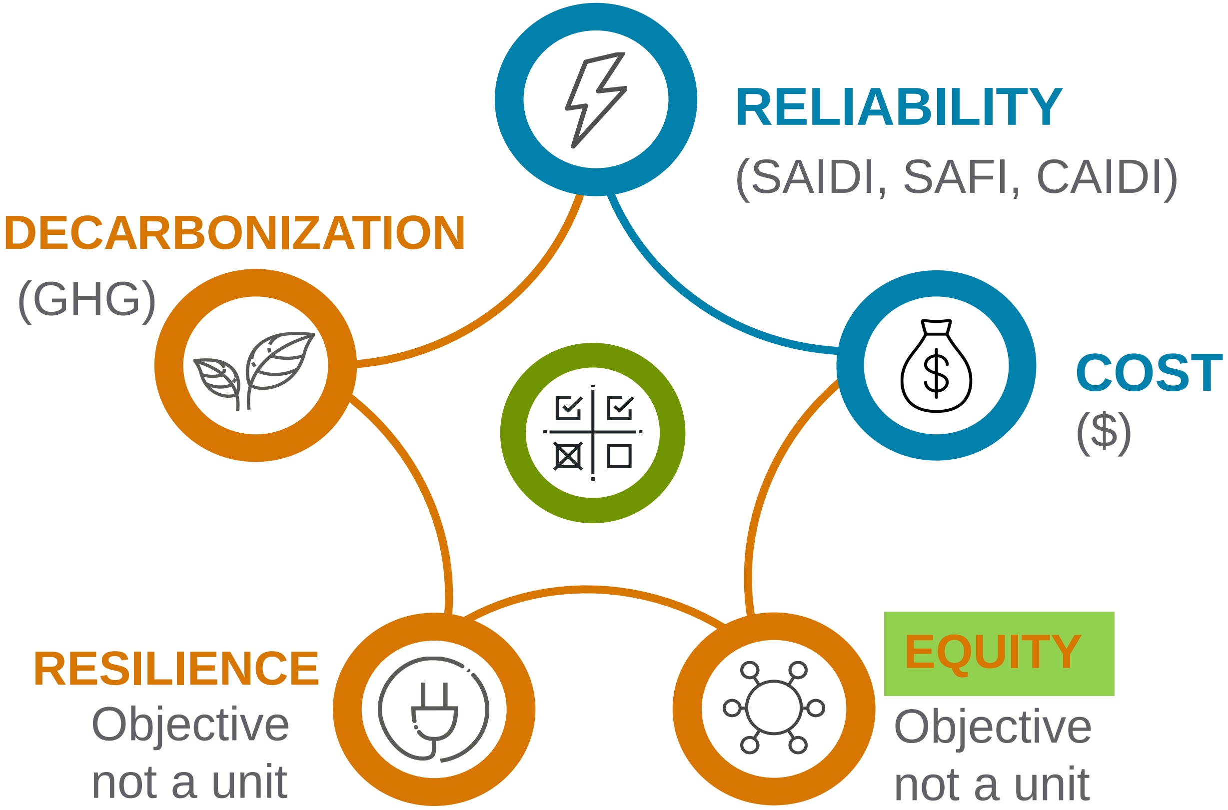
Emerging Objectives in Grid Planning

- Traditionally electric grid planning strives to maintain **safe, reliable, efficient, and affordable** service for current and future customers.
- As policies, social preferences, and the threat landscape evolve, additional considerations for power system planners are emerging, including **decarbonization, resilience, and <u>energy equity and justice</u>.**
- Relative to traditional objectives, these emerging objectives are not well integrated into grid planning paradigms.



Context

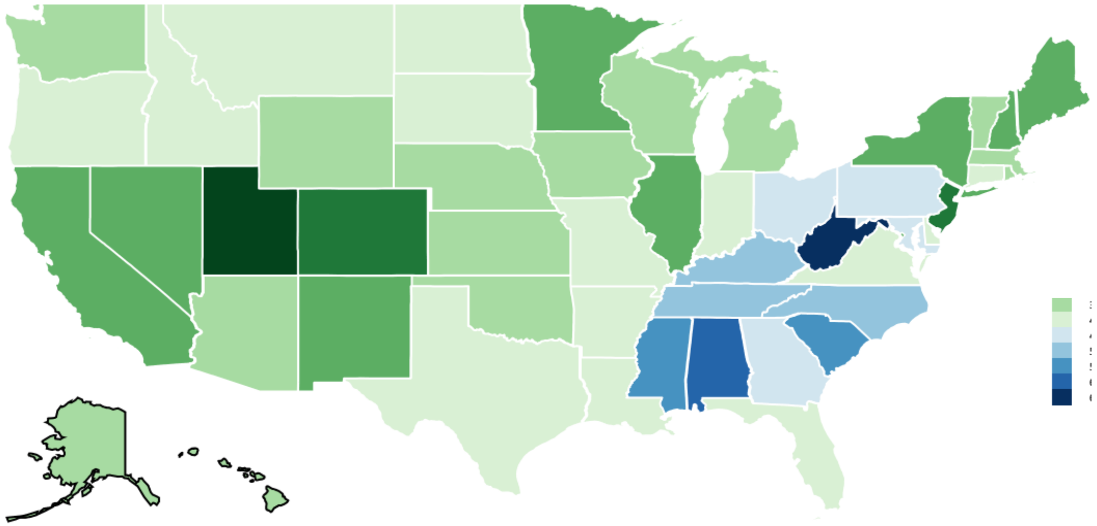
Energy justice and equity examinations uncover the reality that not all customers have the same needs of the energy system. For example:

- Elderly and disabled populations use energy in different ways and have different vulnerability profiles
- Low-income households spend a higher percentage of their income on energy bills, relatively three times higher than affluent households (i.e., 6% of income on energy bills is a high energy burden and 10% is a severe energy burden)

There is a clear demand for explicit work on energy equity and stakeholder engagement. More analysis can be done around:

- Differentiating needs & interactions by demographics (age, race, health, rural, deep poverty) and compound, cumulative effects
- Understanding the relationships between policies and grid futures and the impact on people
- Designing technologies to be safer, to support well-being, and to include life-cycle implications
- Recognizing the procedural limitations of energy system decision-making

Average Residential Electricity Cost Burden – Jan 2016



https://www.pnnl.gov/news-media/mapping-electricity-affordability

% HH Income Spent on Electricity

- 0 to 2.5
- 2.5 to 3.1
- 3.1 to 3.6
- 3.6 to 4.1
- 4.1 to 4.7
- 4.7 to 5.2
- 5.2 to 5.8
- 5.8 to 6.3
- 6.3 to 6.8
- 6.8 to 7.4

Environmental and Energy Justice: Definitions

Environmental Justice

"The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no population, due to policy or economic disempowerment, is forced to bear a disproportionate share of the negative human health or environmental impacts of pollution or environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local and tribal programs and policies."[1]

Energy Justice

"Integrating justice principles, fairness, and social equity into energy systems and energy system transitions."[2]

Just Transition

"A transition away from the fossil-fuel economy to a new economy that provides dignified, productive, and ecologically sustainable livelihoods; democratic governance; and ecological resilience."[3]

Energy Equity

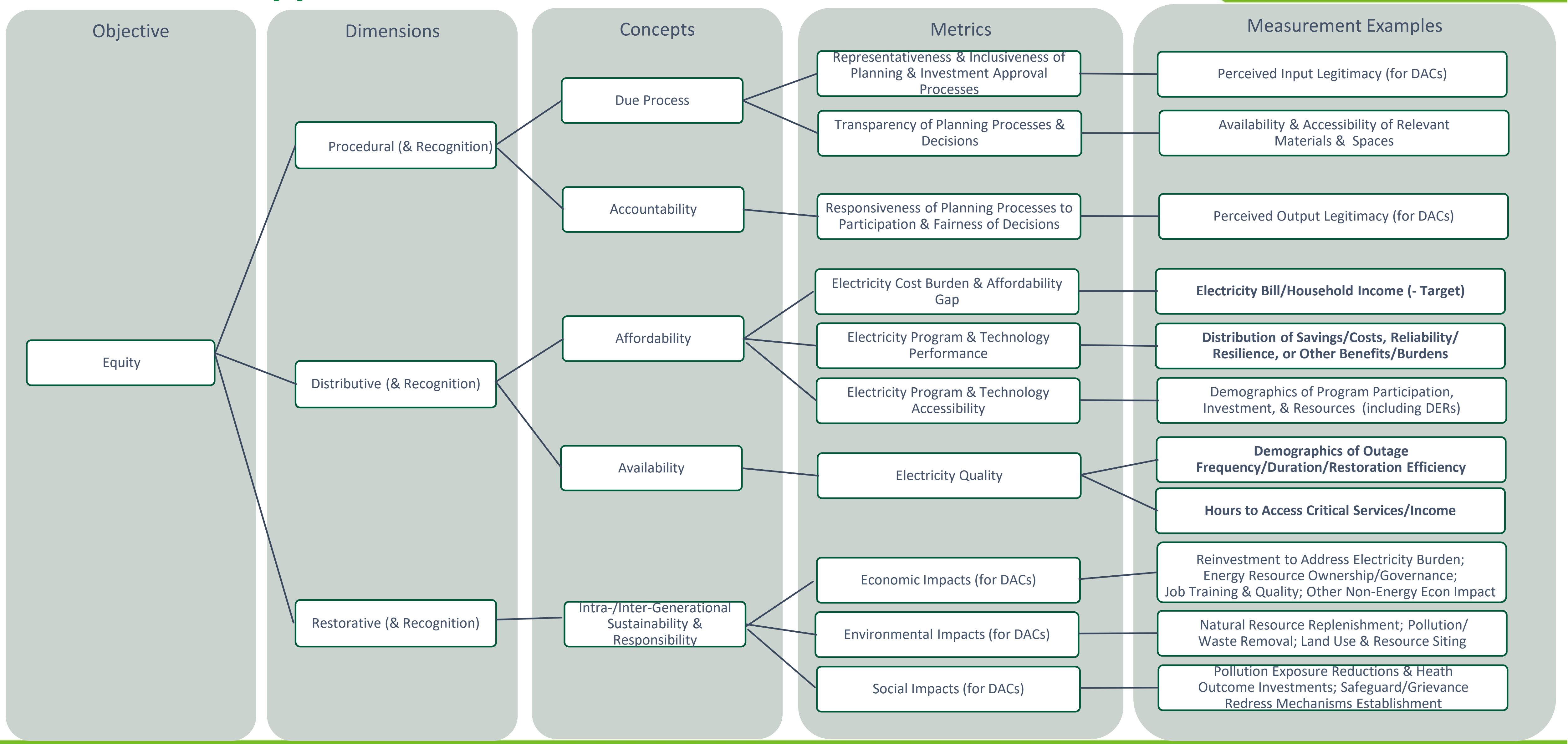
"Energy equity recognizes that disadvantaged communities have been historically marginalized and overburdened by pollution, underinvestment in clean energy infrastructure, and lack of access to energy-efficient housing and transportation. **An equitable energy system is one where the economic, health, and social benefits of participation extend to all levels of society, regardless of ability, race, or socioeconomic status. Achieving energy equity requires intentionally designing systems, technology, procedures, and policies that lead to the fair and just distribution of benefits in the energy system."**[4]

[1] https://www.epa.gov/environmentaljustice/learn-about-environmental-justice
[2] https://link.springer.com/article/10.1007/s40518-021-00184-6
[3] https://iejusa.org/glossary-and-appendix/#glossary_of_terms
[4] https://www.pnnl.gov/projects/energy-equity

Equity Definition

- Equity is the ability of the electric system to fairly distribute burdens and benefits and to ensure that electricity decision-making procedures are inclusive of and responsive to *all* affected stakeholders, including those historically burdened by and excluded from planning for the electricity system.
- To achieve equity in the electricity system—especially in the transition to a more sustainable energy sector—systems, technologies, procedures, and policies must be designed in a way to enable the fair and just distribution of benefits in the energy system through:
  - **Procedural and recognition justice** (i.e., due process, accountability, and transparency of grid planning processes);
  - **Distributive justice** (i.e., affordability and availability of electricity services and transition-enabling programs and technologies); and
  - **Restorative justice** (i.e., intra- and inter-generational sustainability and responsibility, including rectifying economic and environmental inequities in the electricity system).

Equity Objective, Dimensions, Concepts, Metrics, and Measurement Approaches



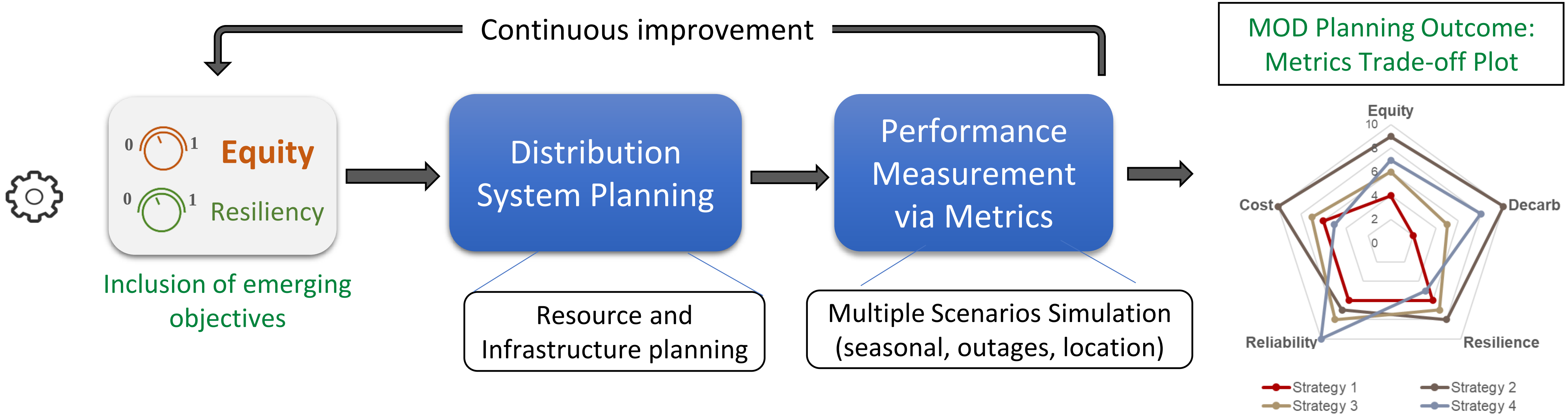
Performance Metrics

Energy Burden	*Equity*
Energy Vulnerability to Outages	*Resiliency, Equity*
Access to black-start DERs	*Resiliency, Equity*
Loss of load (SAIFI/SAIDI)	*Reliability, Equity*
Energy Served from DERs	*Decarb, Equity*
Cost of Assets Upgrade	*Cost, Equity*
Impact on Energy Consumption due to Energy Efficiency Program	*Efficiency, Equity*

Example Metrics	
Energy Burden	$\frac{Annual\ utility\ bills}{Annual\ household\ income}$
SAIFI	$\frac{Total\ \#\ of\ customers\ interrupted}{Total\ \#\ of\ customers\ served}$
E3B Investment*	$\%\ of\ low\ income\ population\ \times\ Total\ residential\ EE\ investment\ (\$)$

*Energy Efficiency Equity Baseline (E3B)

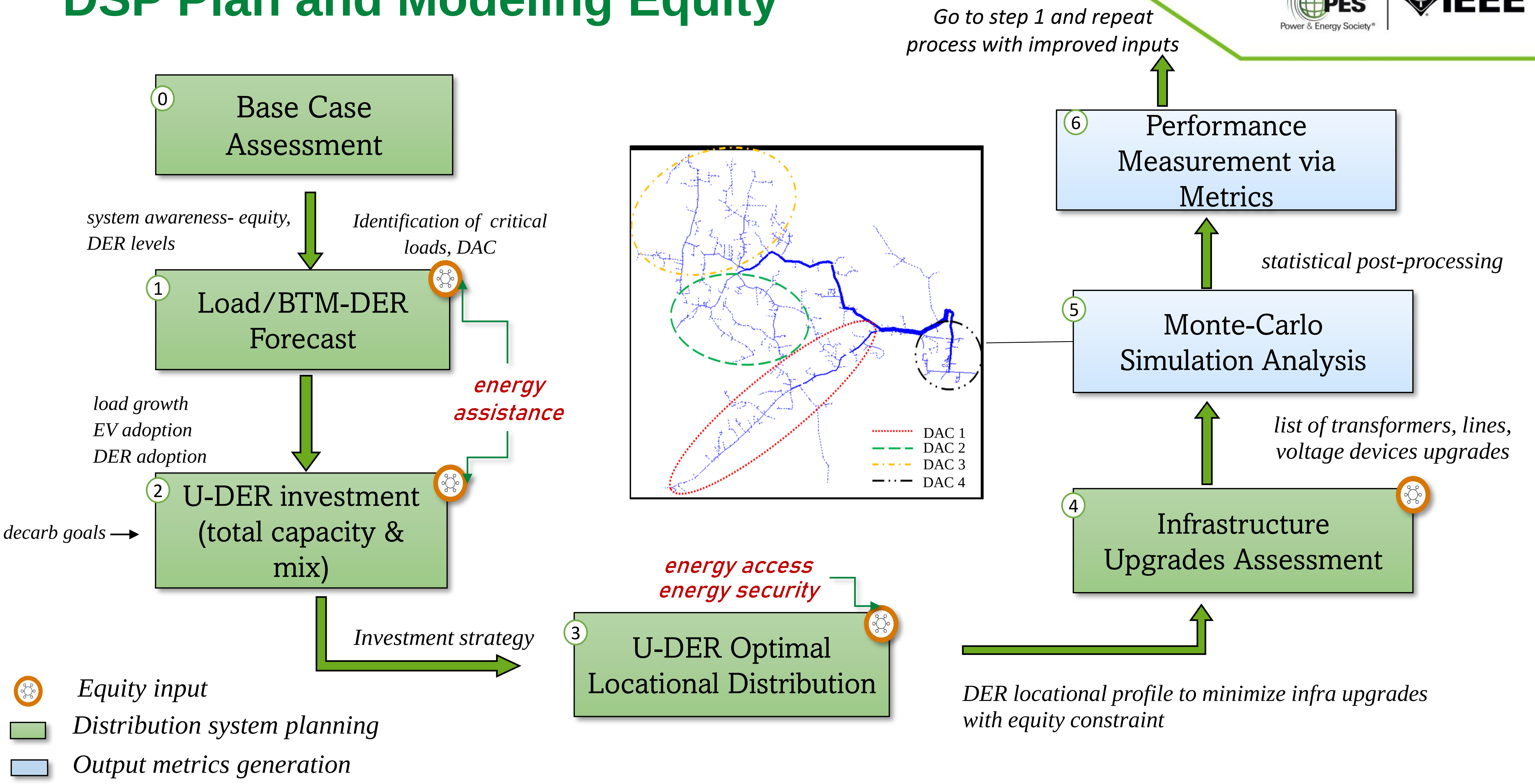
Simulation Framework



Different investment strategies can be analyzed by adjusting the dial of emerging objective considerations:

- ✓ Equity = 0 : business as usual
- ✓ Equity = 1: high equity consideration

DSP Plan and Modeling Equity



Modeling Equity in DSP Process

	Equity Characteristics	Planning process	Potential Impact on Outcome
1	Energy assistance/demand response to DAC	Load Forecast	Reduced energy burden for DAC
2	DER incentives/rebates	DER adoption	Increased DER adoption in DAC
3	x% of DAC load served from DER	Utility DER locational distribution	Improved energy access and security
4	A community center with black-start DER units for outages	Utility DER locational distribution/ microgrid planning	Improved resiliency in DAC and reduced energy vulnerability
5	Necessary infra upgrade to host DERs in DAC regions	Infrastructure upgrade planning	Improved resiliency in DAC

Monte-Carlo Methodology

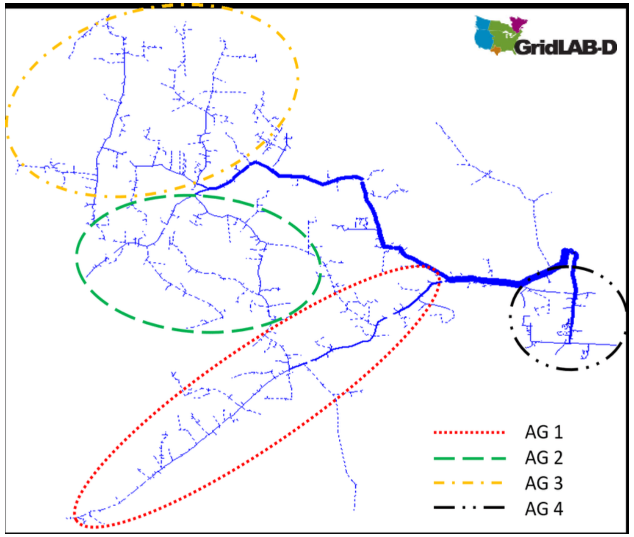
- An alternative to expansive real-world data requirement from utility
- Provides statistical insights with bounded parameters range

Uncertain Parameters

- House-level load growth
- List of possible outages/ contingencies
- House-level DER adoption
- Boundaries for DAC regions
- Potential utility-owned DER locations
- Load and DER profiles

100s of scenarios

Monte Carlo simulation on feeder



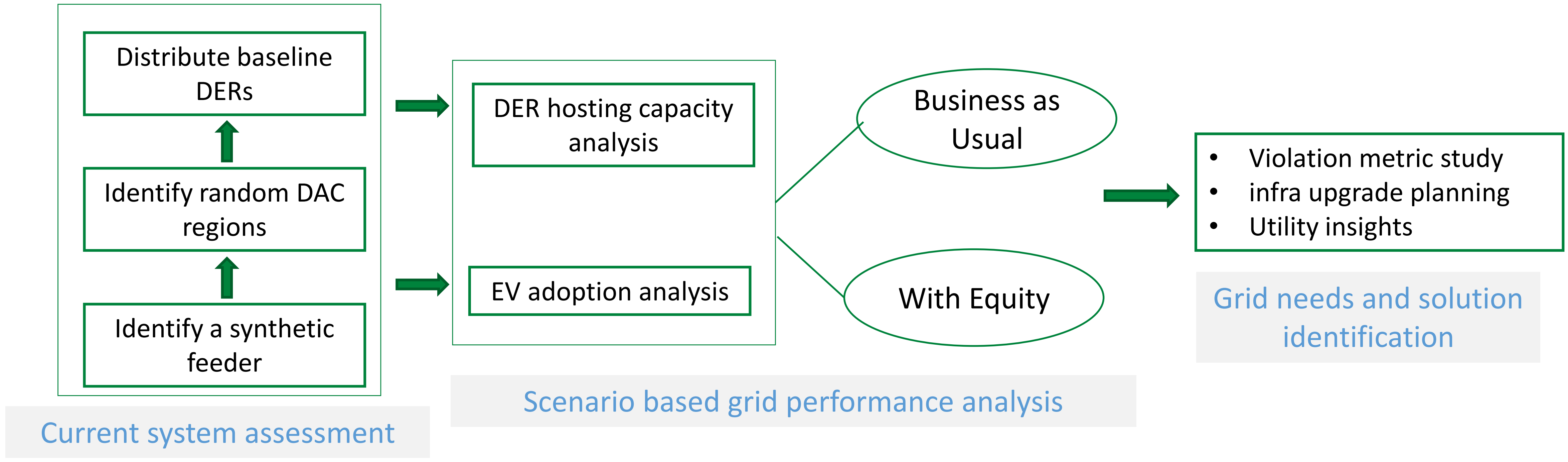
Metrics

- Losses
- Energy served from renewables
- SAIFI/SAIDI
- Energy burden
- Energy access
- Energy security
- Cost analysis

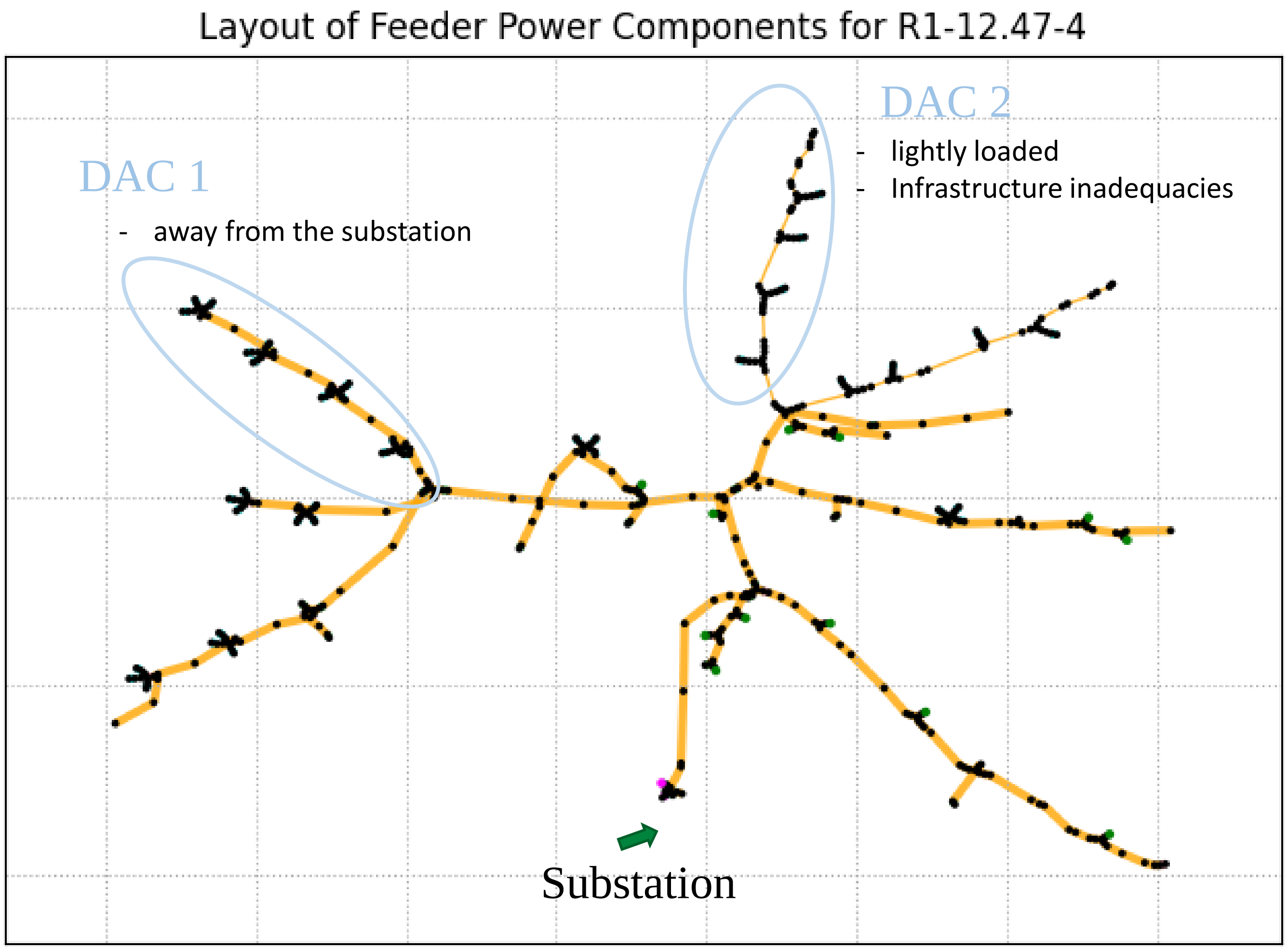
Equity Consideration: System Readiness

- Sub-problem:

To analyze the *technical readiness* of the distribution system with the inclusion of equity parameters in DER hosting and EV adoption



PNNL Prototype Feeder



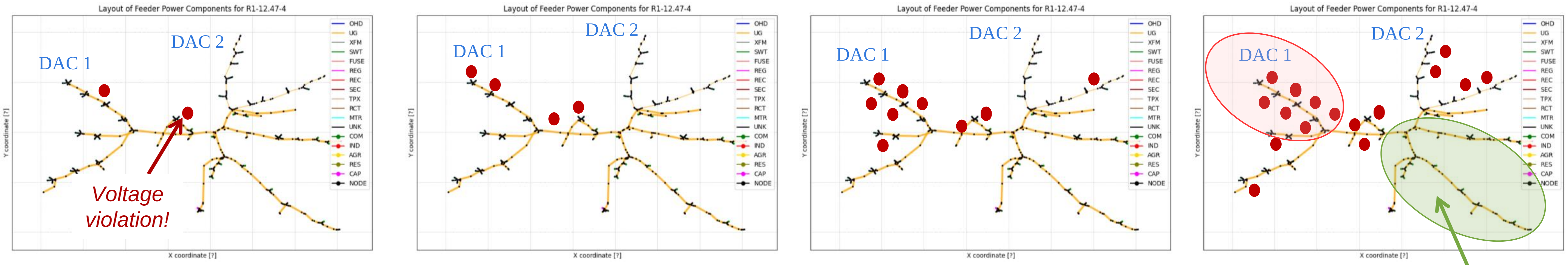
- A 300-node taxonomy feeder representing west-coast heavy sub-urban area

Service transformers	50
Residential customers	380
Commercial customers	12
Total load	5.3 MW

- Randomly identified 2 DAC regions
  - DAC:130 customers
  - Non-DAC: 250 customers

PV Hosting Capacity Analysis

- A simplified PV hosting analysis to identify unsuitable PV locations with over-voltage violations
- Voltage violations: voltage at a node violating ANSI limits (~ 0.95-1.05 pu)



80% PV

100% PV

120% PV

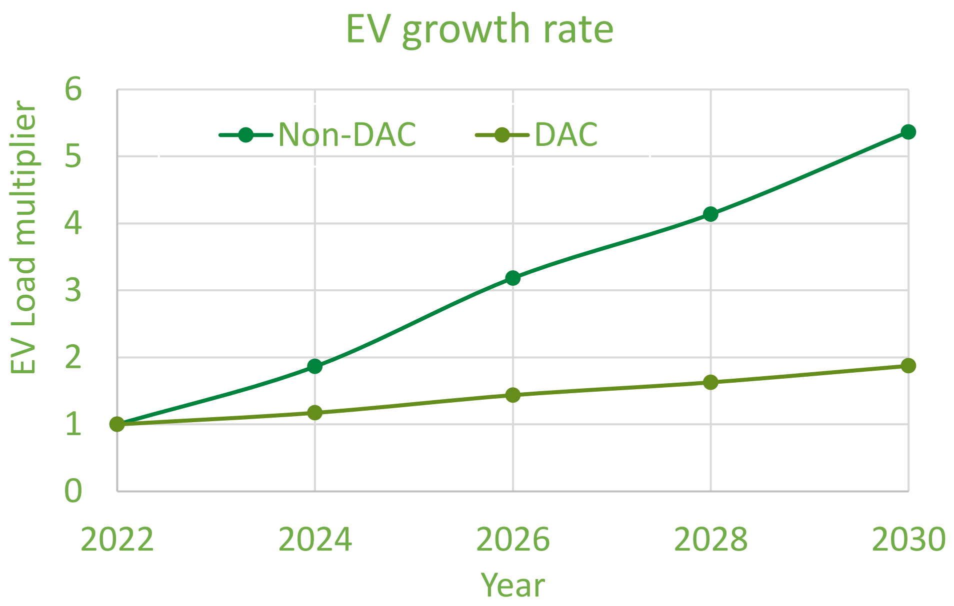
140% PV

Suitable locations for PV

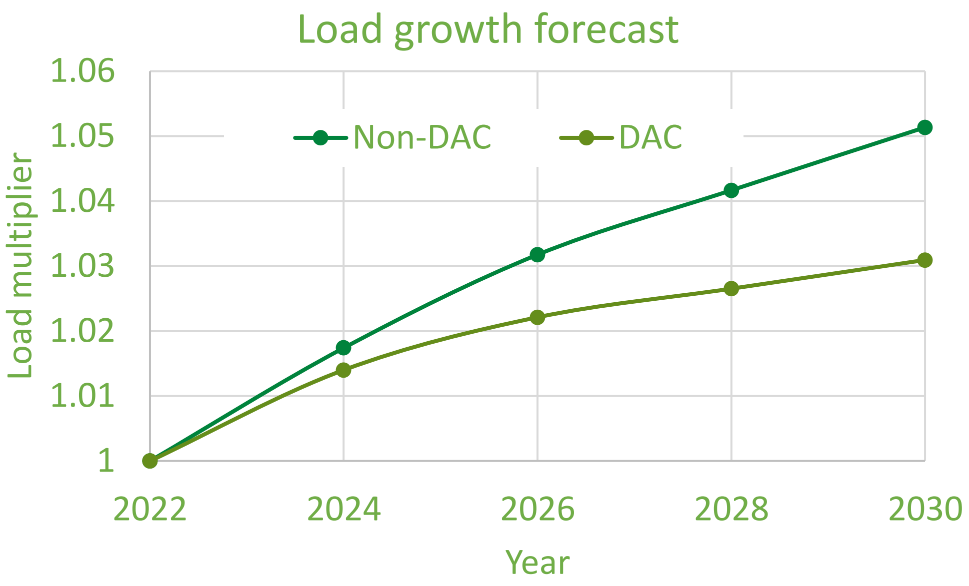
- DAC-1 turns out to be a region with high voltage violations with increasing solar PV penetration, making it unsuitable for hosting solar PV
- Bottom right region of the feeder is better location for solar PV installments

** Note that the results are only for a specific feeder with assumed definitions of DAC regions*

EV Adoption Analysis



Source: Historical sales data, Evadoption.com



Source: https://www.eia.gov/outlooks/aeo/electricity/sub-topic-01.php

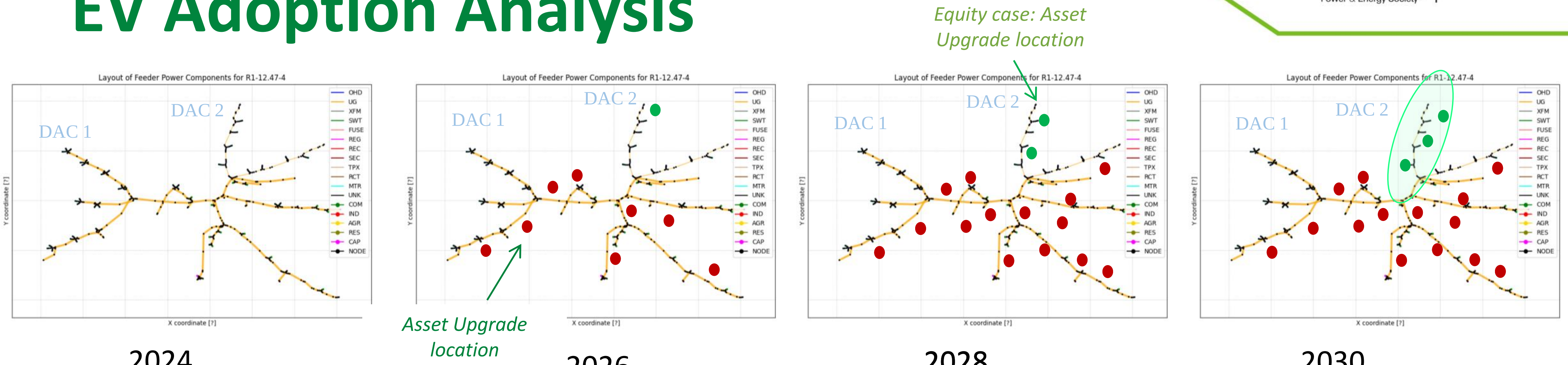
- Current (2022) EV adoption is assumed to be 25% and 5% for non-DAC and DAC regions
- DAC region growth is assumed to be 20% of non-DAC

- Base load (kW) for DAC and non-DAC are different
- DAC are assumed to have lower growth rate for loads

With Equity: DAC regions are assumed to have same growth as non-DAC region for EV and load

** Note that the results are only for a specific feeder with assumed definitions of DAC regions*

EV Adoption Analysis



2024 2026 2028 2030

of assets that need upgrade due to EV adoption

Year	Transformers		
	Non-DAC	DAC-BAU	DAC-Equity
2022	0	0	0
2024	0	0	0
2026	8	0	1
2028	23	0	3
2030	30	0	4

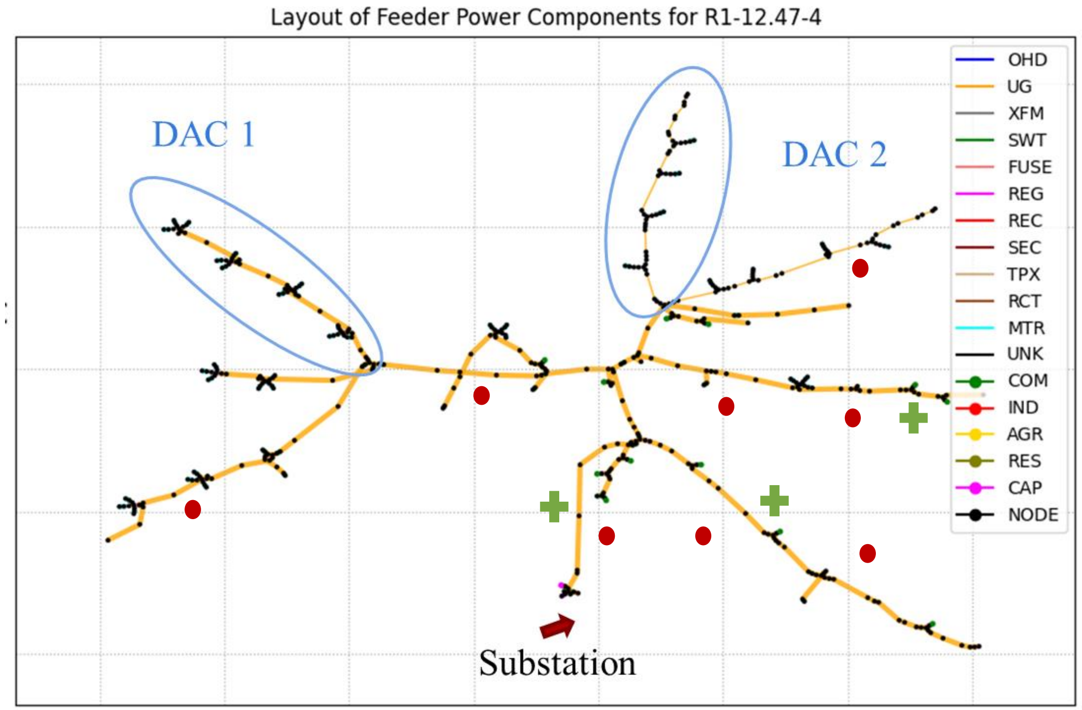
Year	Line conductors		
	Non-DAC	DAC-BAU	DAC-Equity
2022	0	0	0
2024	0	0	0
2026	2	0	0
2028	6	0	2
2030	8	0	3

- Power-flow analysis for each year provides thermal violations of transformer and conductors due to EV adoption.
- In BAU: all upgrades are needed in non-DAC region;
- With equitable EV adoption: DAC region also need upgrade

** Note that the results are only for a specific feeder with assumed definitions of DAC regions*

Planning: BAU

- Utility-level DER allocation: Most DERs should be located at
  - High hosting capacity locations to avoid voltage mitigation solutions
  - closer to high EV load locations to avoid asset upgrade
- Asset Upgrade: Transformers and lines should be upgraded at locations obtained from the analysis in non-DAC region to manage EV adoption
- In this particular case, DAC regions
  - do not qualify for DERs due to low PV hosting capacity and
  - do not qualify for upgrades due to low EV adoption forecast



- Transformer and line upgrade
- Utility-level DER allocation

** Note that the results are only for a specific feeder with assumed definitions of DAC regions*

Planning: with Equity

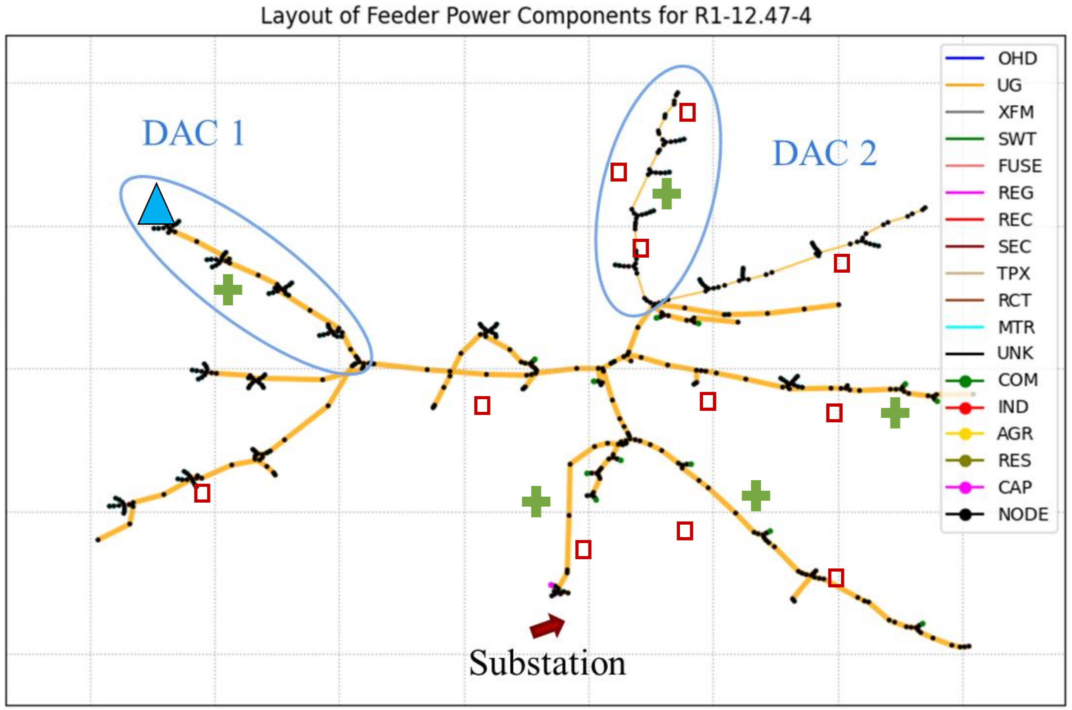
Utility-level DER allocation: DACs should have equitable PV hosting capacity

- A voltage mitigation solution needs to be applied e.g. voltage regulator installation

Asset Upgrade: DACs should have equitable EV hosting capacity

- Transformers and lines should be upgraded in DAC-2 region to ensure technical readiness to host equitable EV adoption

In a different feeder with different DAC definitions, we may have different solution identification.



- Transformer and line upgrade
- Utility-level DER allocation
- Voltage regulator installation

** Note that the results are only for a specific feeder with assumed definitions of DAC regions*

Planning: with Equity

- Planning with equity has higher upgrade cost than BAU in order to ensure equitable DER and EV hosting capacity of DAC regions.

- However, in long-term, it has potential to provide following benefits:
  - Ancillary services from DER inverters such as volt/var, freq/watt
  - Equitable DER access
  - Improved hosting capacity of DAC regions likely to make system more equitable and resilient

- Impact analysis of system readiness for equitable DER hosting on various other performances such as cost, and resiliency will reveal the trade-off.

Conclusion and Next Steps

- DAC regions may have relatively lower DER hosting capacity due to locational disadvantage. This leads to reduced DER access to DAC region
- BAU EV adoption prediction in DAC regions causes relatively slower infrastructure upgrade compared to the rest of the feeder which may not be sufficient for equitable EV adoption future. Its impact on DAC regions' resiliency need to be analyzed.
- Next steps:
  - Work with utilities to gather real-world data for further analysis
  - Cost and benefit analysis of equitable hosting capacity of DAC regions
  - Impact of low EV adoption and associated slower infra upgrade on the resiliency of DAC regions
  - Develop metrics to quantify equity and resiliency impact

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Project site: https://www.pnnl.gov/projects/mod-plan